

FIG.1A

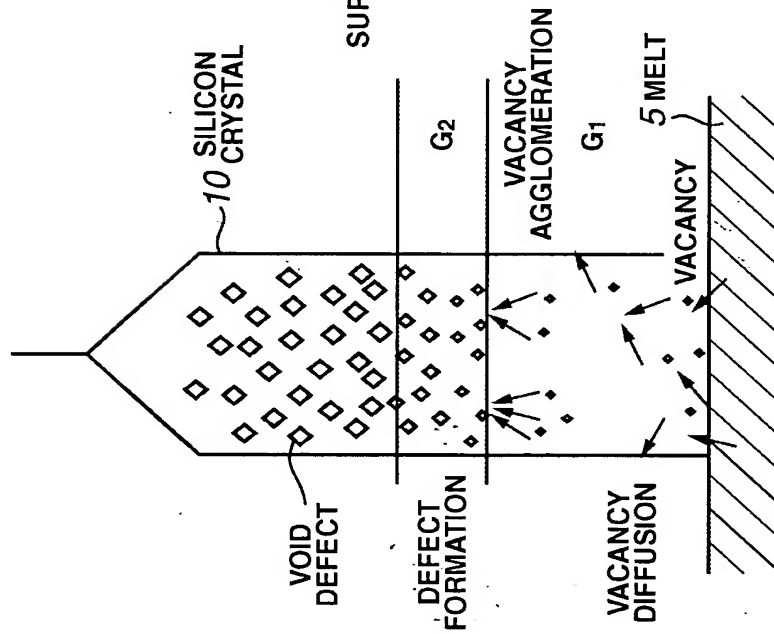
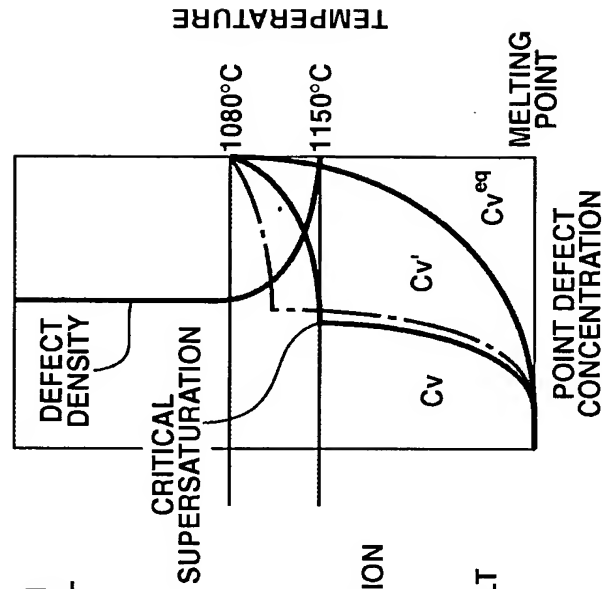


FIG.1B



CONCEPTUAL DIAGRAM OF
DEFECT FORMATION MECHANISM

FIG.2

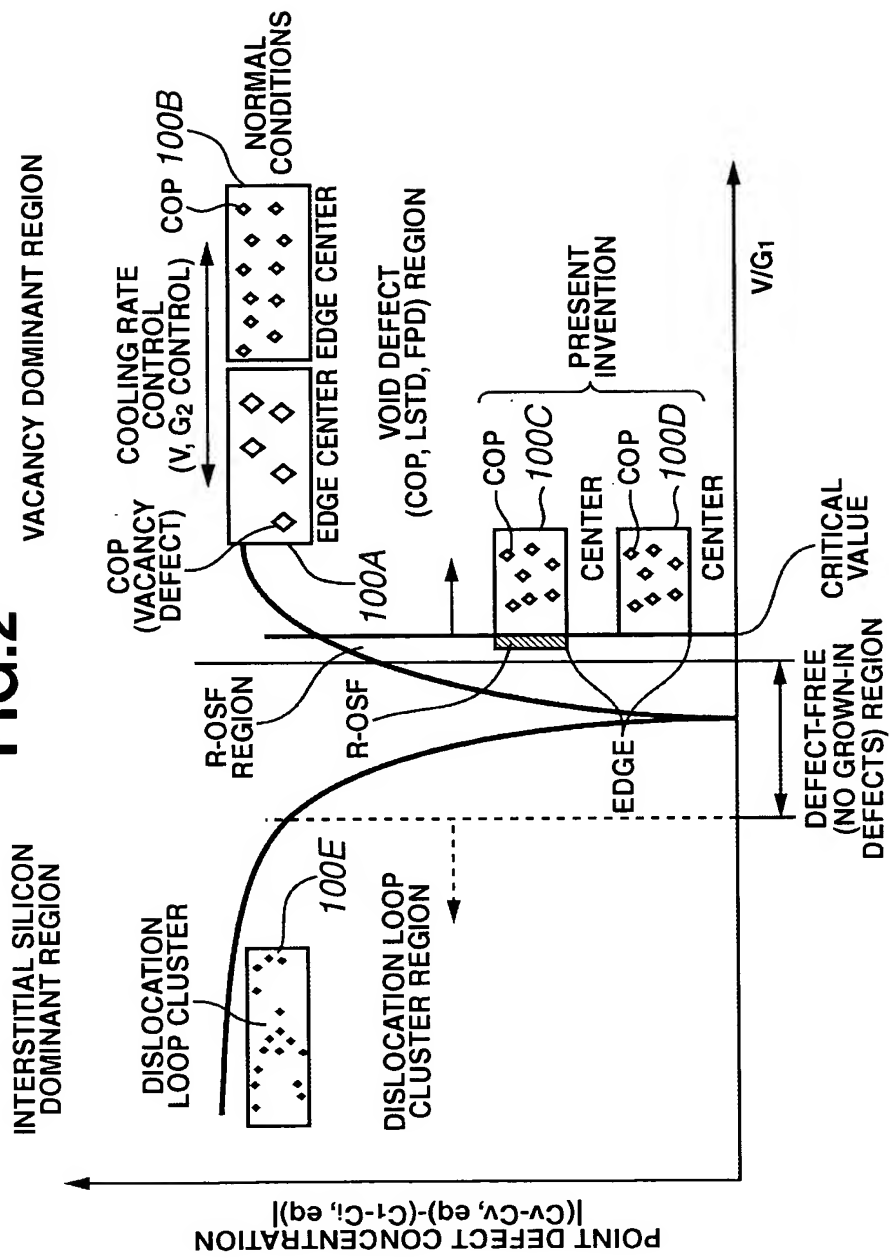
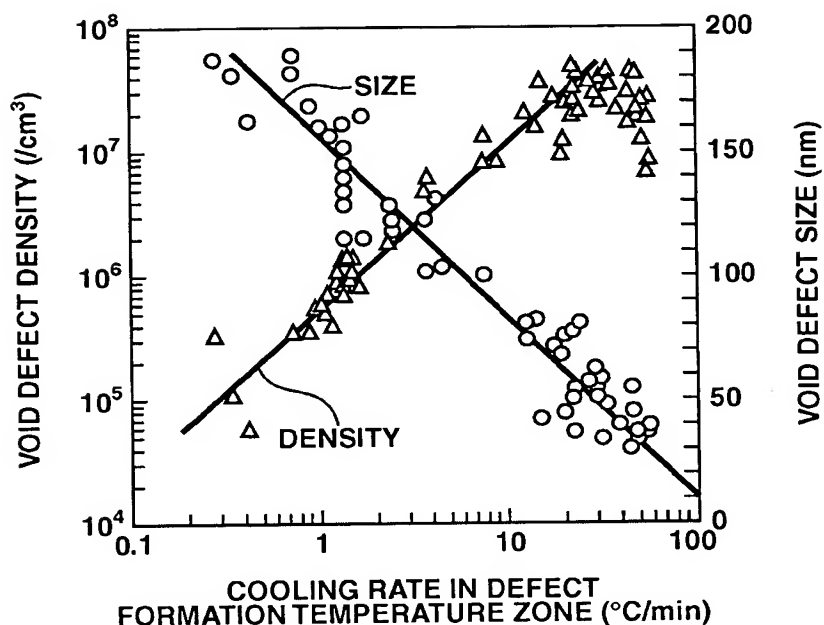
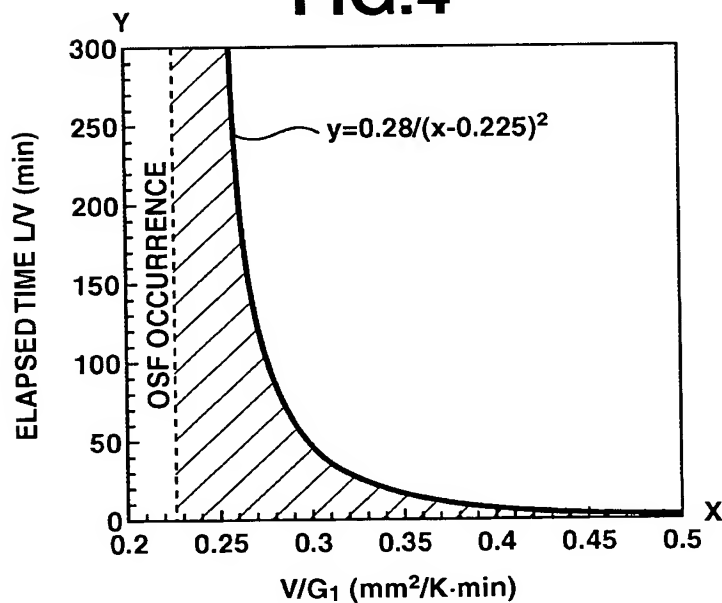


DIAGRAM OF RELATIONSHIP BETWEEN DEFECT TYPE AND POINT DEFECT (VACANCY, INTERSTITIAL SILICON) CONCENTRATION

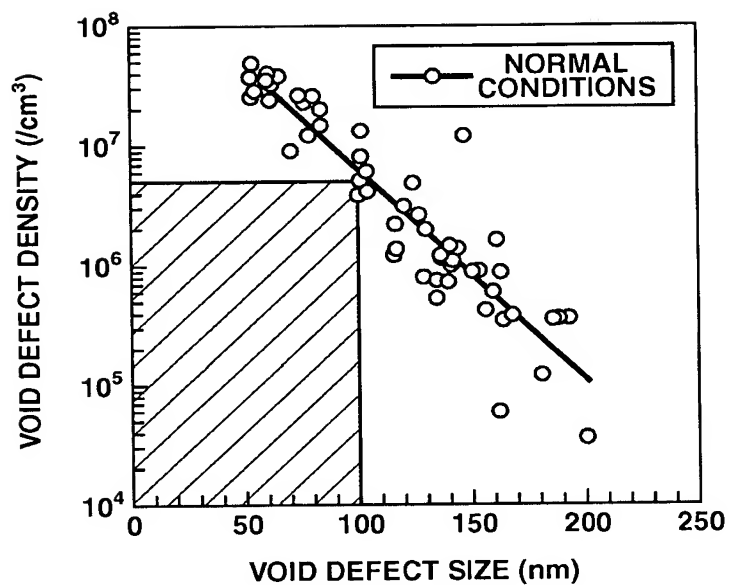
FIG.3

RELATIONSHIP BETWEEN COOLING RATE
AND VOID DEFECT DENSITY AND SIZE

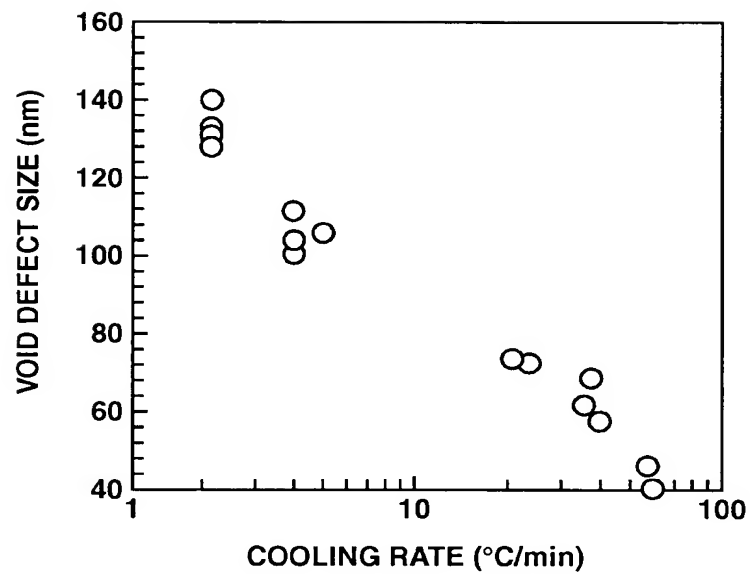
FIG.4

RELATIONSHIP BETWEEN V/G_1
AND ELAPSED TIME (PRIOR ART)

FIG.5



RELATIONSHIP BETWEEN VOID
DEFECT DENSITY AND VOID DEFECT SIZE

FIG.6

RELATIONSHIP BETWEEN COOLING RATE AT 1100°C
AND VOID DEFECT SIZE (WHEN V/G_1 IS AT LEAST
ABOUT TWO TIMES THE CRITICAL VALUE)

RELATIONSHIP BETWEEN SILICON
WAFER RADIAL POSITION AND V/G_1

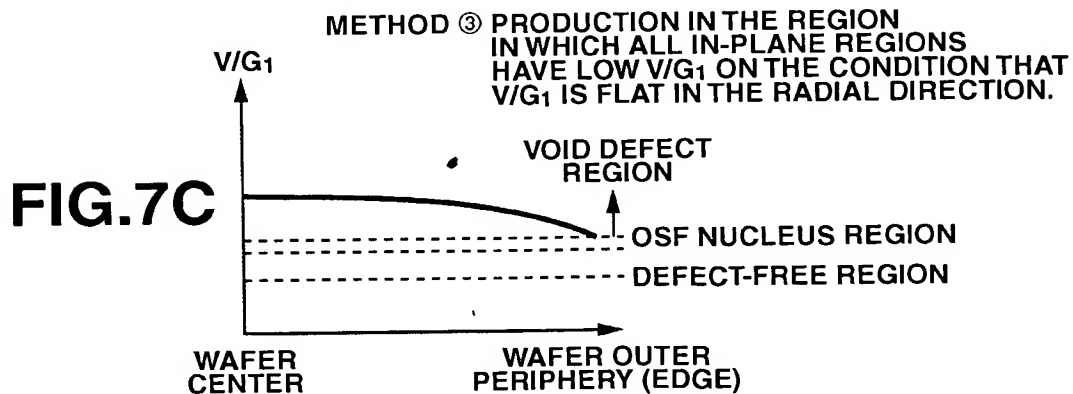
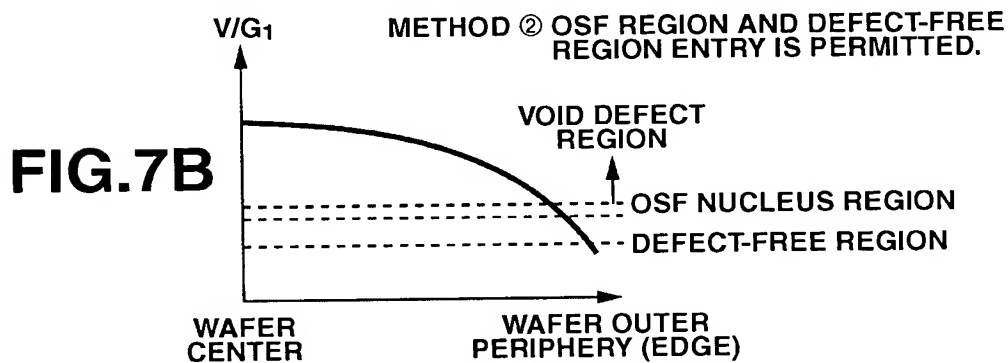
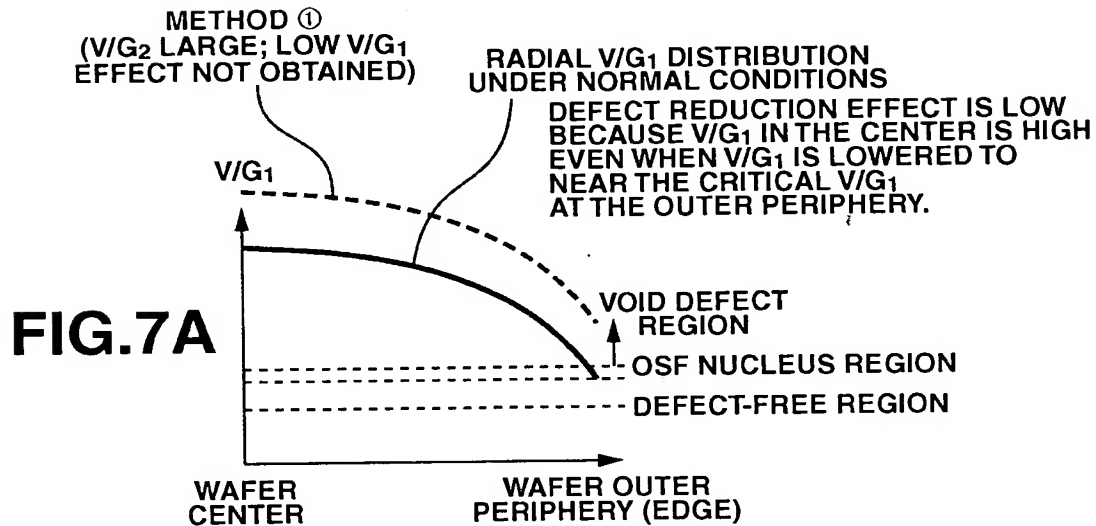


FIG.8

RELATIONSHIP BETWEEN PULLING RATE,
SOLID-LIQUID INTERFACE SHAPE, AND OSF OCCURRENCE
PULLING RATE UNDER NORMAL CONDITIONS

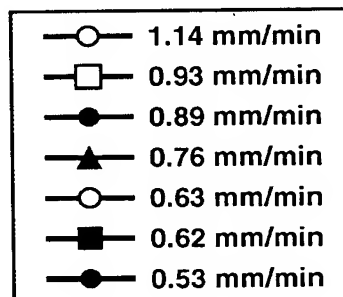
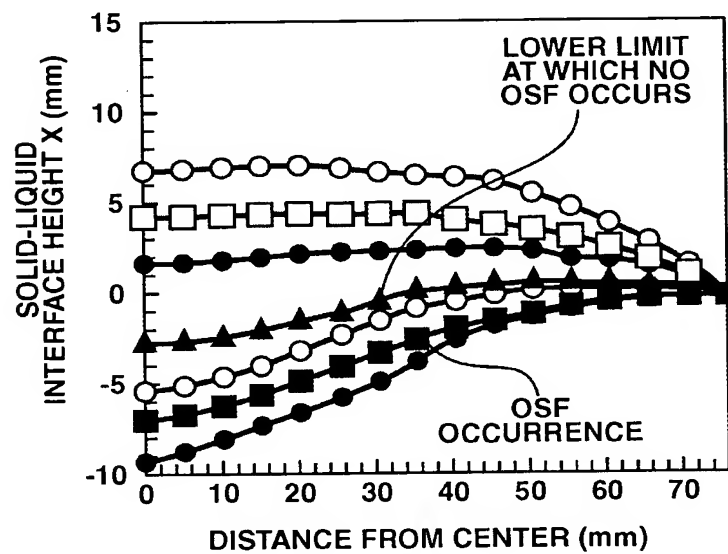
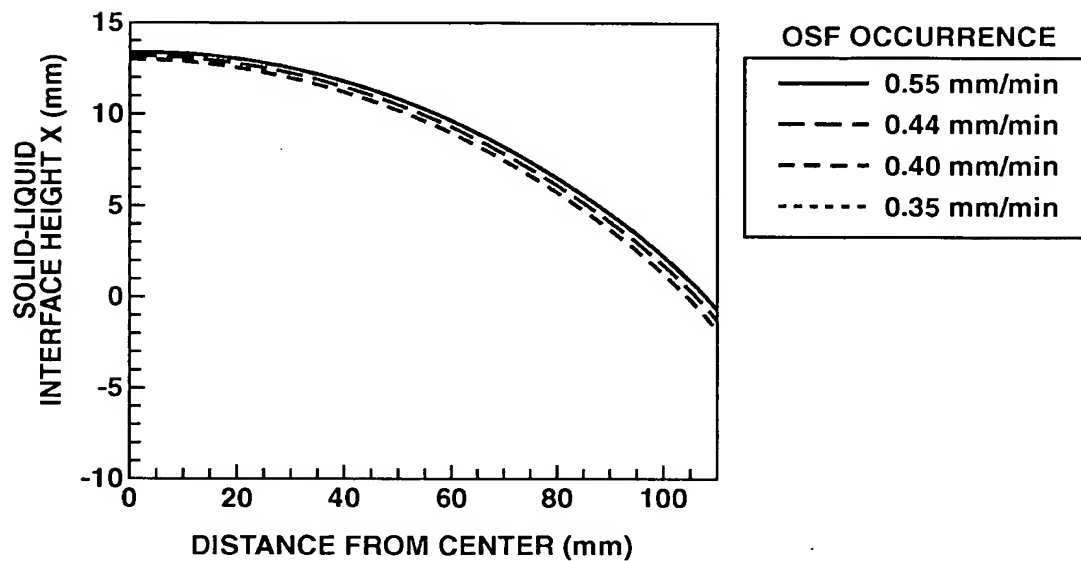


FIG.9

RELATIONSHIP BETWEEN PULLING RATE,
SOLID-LIQUID INTERFACE SHAPE, AND OSF
OCCURRENCE PULLING RATE UNDER CONDITION OF
APPLICATION OF 3000 G HORIZONTAL MAGNETIC FIELD

**FIG.10**

RELATIONSHIP BETWEEN PULLING RATE,
SOLID-LIQUID INTERFACE SHAPE, AND OSF OCCURRENCE
PULLING RATE UNDER CONDITION OF COOLER INSTALLATION

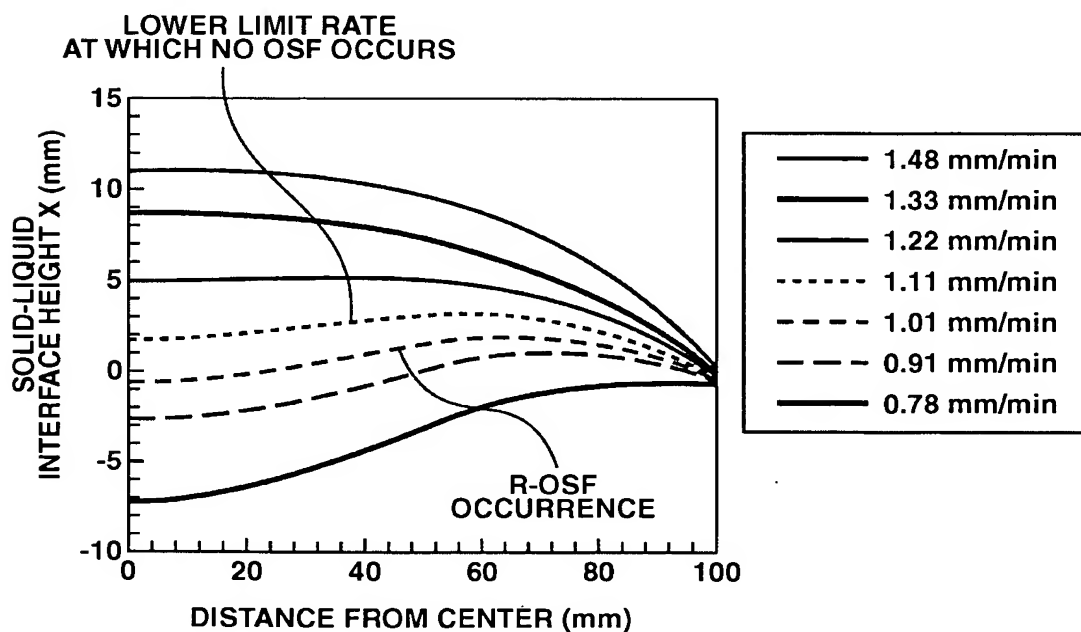
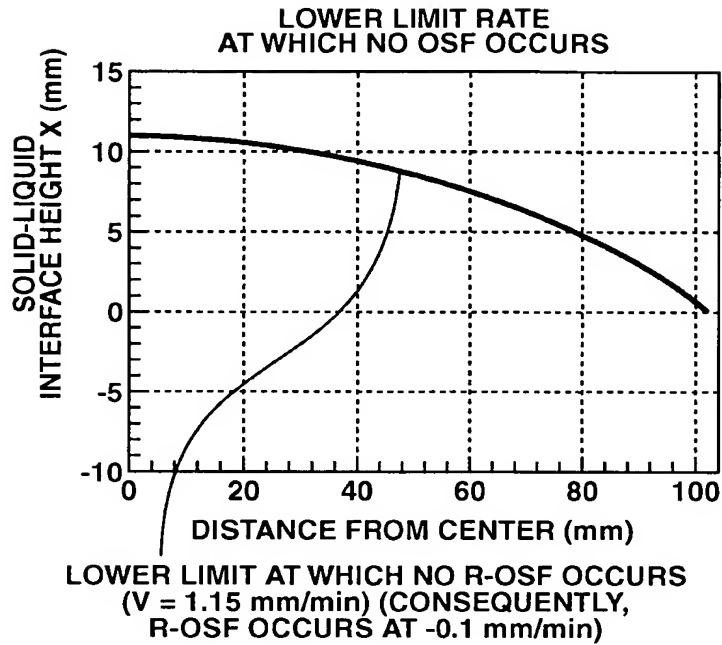
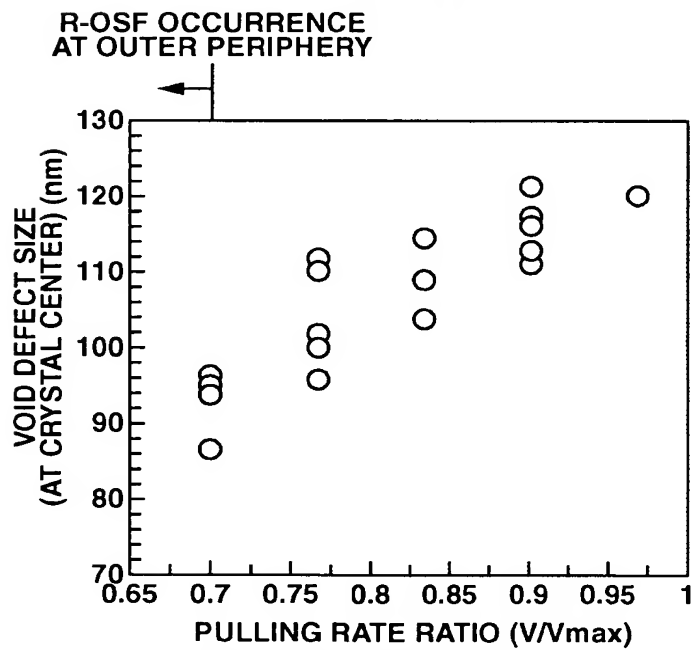
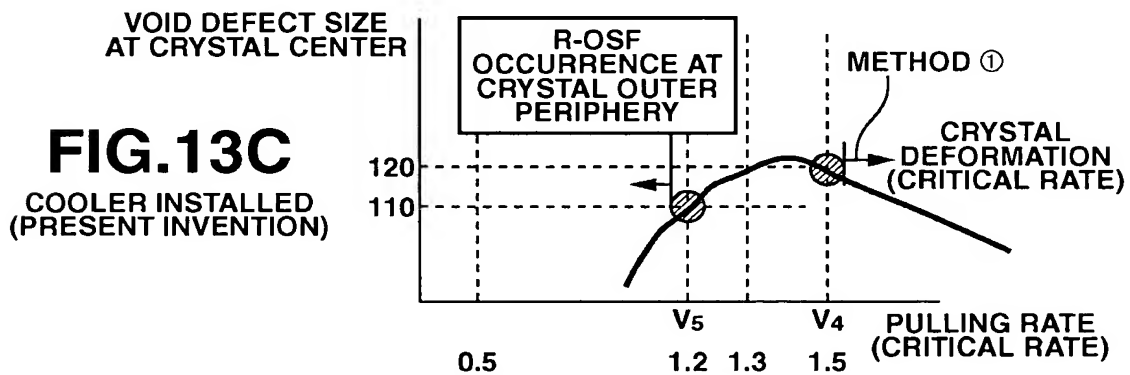
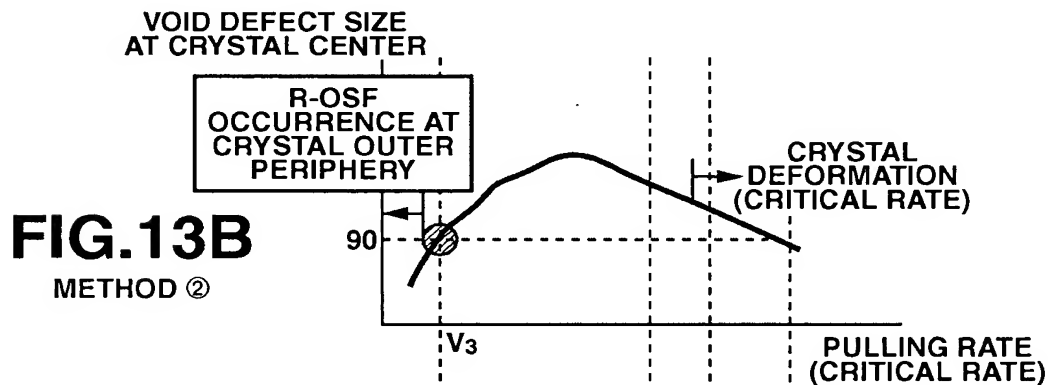
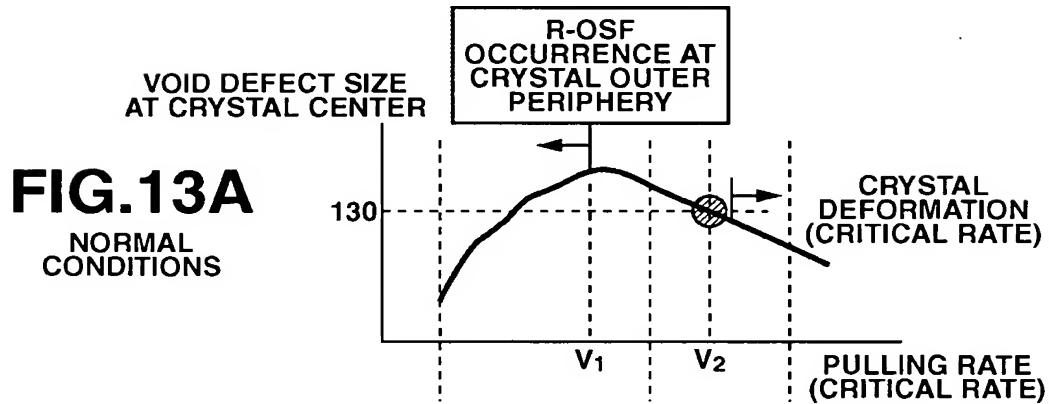


FIG.11**FIG.12**

RELATIONSHIP BETWEEN VOID DEFECT SIZE
AT CENTER OF CRYSTAL AND PULLING RATE RATIO
UNDER CONDITION OF COOLER INSTALLATION

RELATIONSHIP BETWEEN PULLING RATE
AND VOID DEFECT SIZE AT CRYSTAL CENTER



CORRESPONDENCE AMONG PULLING RATE RATIO,
 PRESENCE OR ABSENCE OF OSF REGION, AND HISTOGRAMS OF
 LPD COUNT PER WAFER UNDER CONDITION OF COOLER INSTALLATION

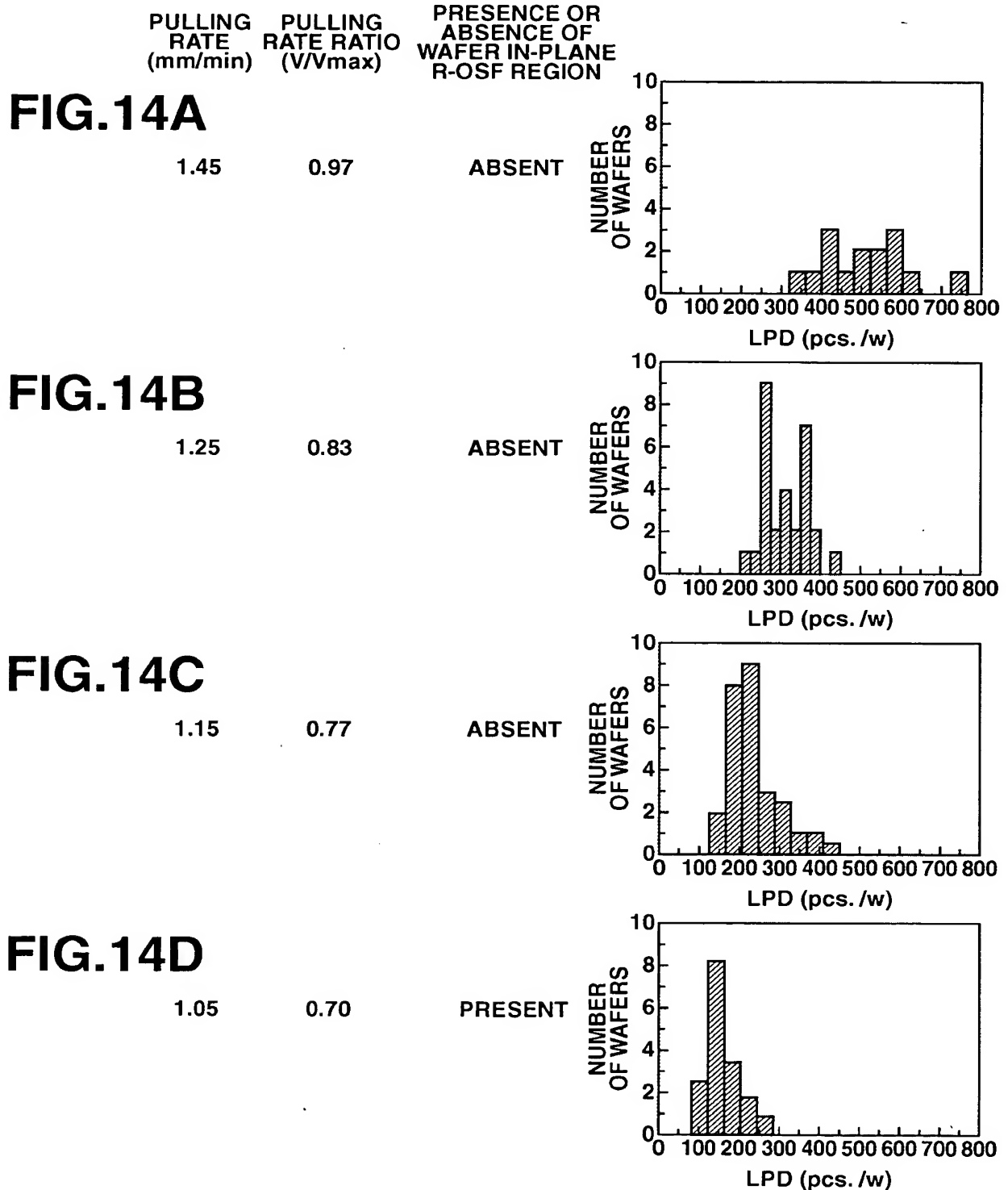
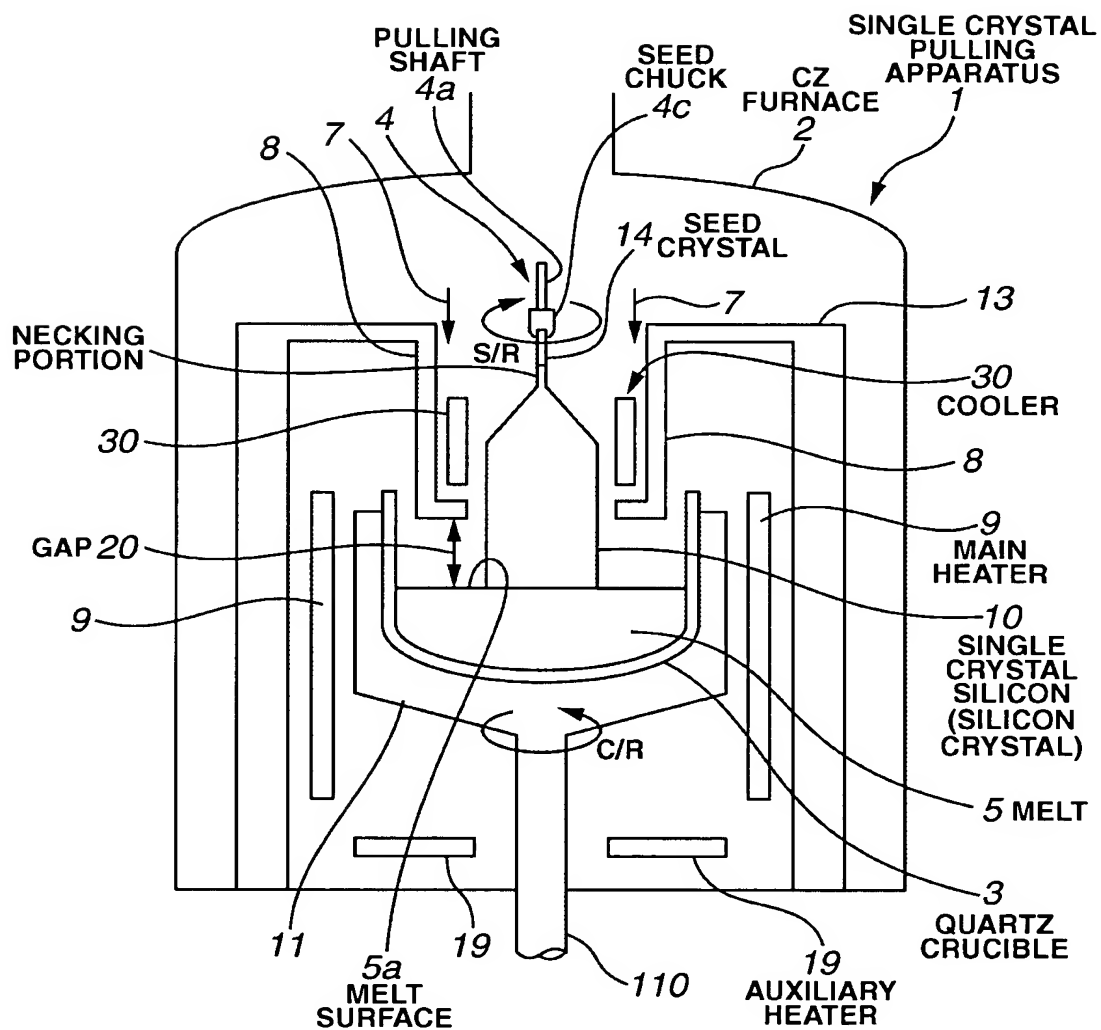
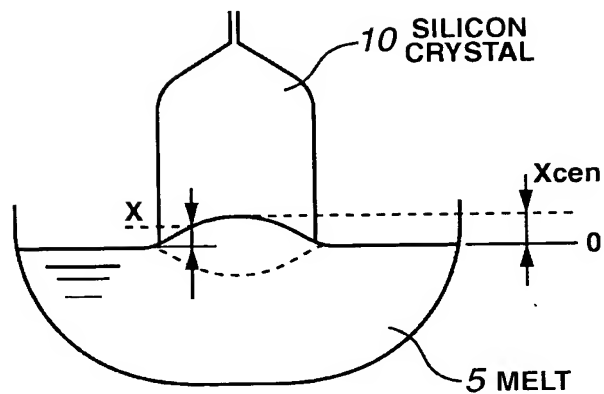


FIG.15



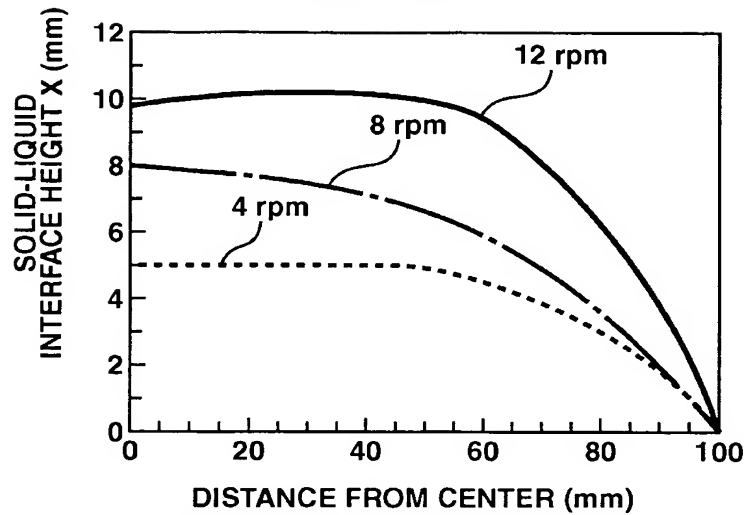
- 4 PULLING MECHANISM
- 4a PULLING SHAFT
- 7 ARGON GAS
- 8 HEAT BLOCKING PLATE
- 10 ROTARY SHAFT
- 11 GRAPHITE CRUCIBLE
- 13 INSULATING CYLINDER

FIG.16**FIG.17**

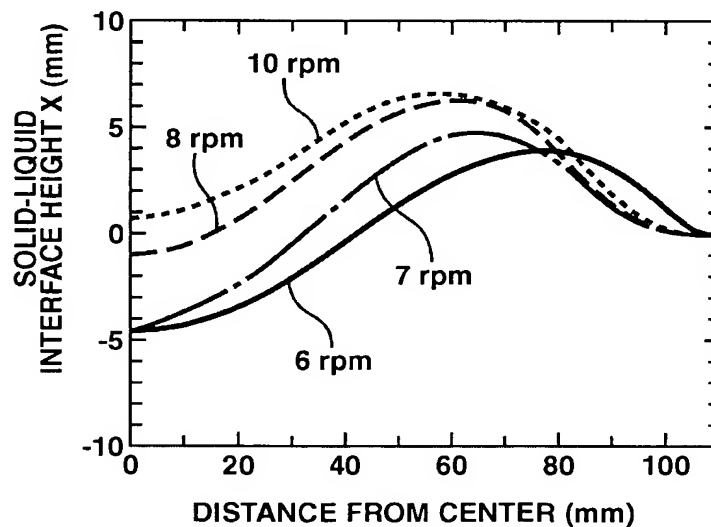
COMPARISON OF CONVENTIONAL COP
REDUCTION METHOD AND PRESENT INVENTION

	REDUCTION IN COP COUNT OF AT LEAST 0.10 μm	PRODUCTIVITY	PRESENCE OR ABSENCE OF R-OSF
METHOD ①	\triangle	\odot	ABSENT
METHOD ②	\bigcirc	\triangle	PRESENT
METHOD ③	\odot	\triangle	ABSENT
PRESENT INVENTION	\odot	\bigcirc	ABSENT

\odot : EXCELLENT, \bigcirc : GOOD, \triangle : FAIR

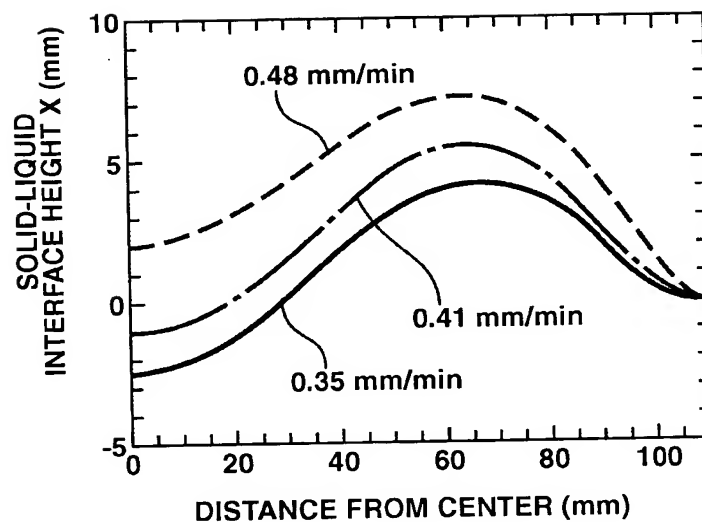
FIG.18

CHANGE IN SOLID-LIQUID INTERFACE SHAPE
WHEN CRYSTAL ROTATION WAS VARIED (OTHER THAN
CRYSTAL ROTATION, ALL PULLING CONDITIONS
WERE THE SAME, NO MAGNETIC FIELD WAS APPLIED)

FIG.19

CHANGE IN SOLID-LIQUID INTERFACE SHAPE
WHEN CRUCIBLE ROTATION WAS VARIED (OTHER THAN
CRUCIBLE ROTATION, ALL PULLING CONDITIONS
WERE THE SAME, NO MAGNETIC FIELD WAS APPLIED)

FIG.20



CHANGE IN SOLID-LIQUID INTERFACE SHAPE WHEN
PULLING RATE WAS VARIED UNDER NORMAL PULLING
CONDITIONS (NO MAGNETIC FIELD APPLIED,
NO COOLER INSTALLED) (OTHER THAN PULLING RATE,
ALL PULLING CONDITIONS WERE THE SAME)

FIG.21

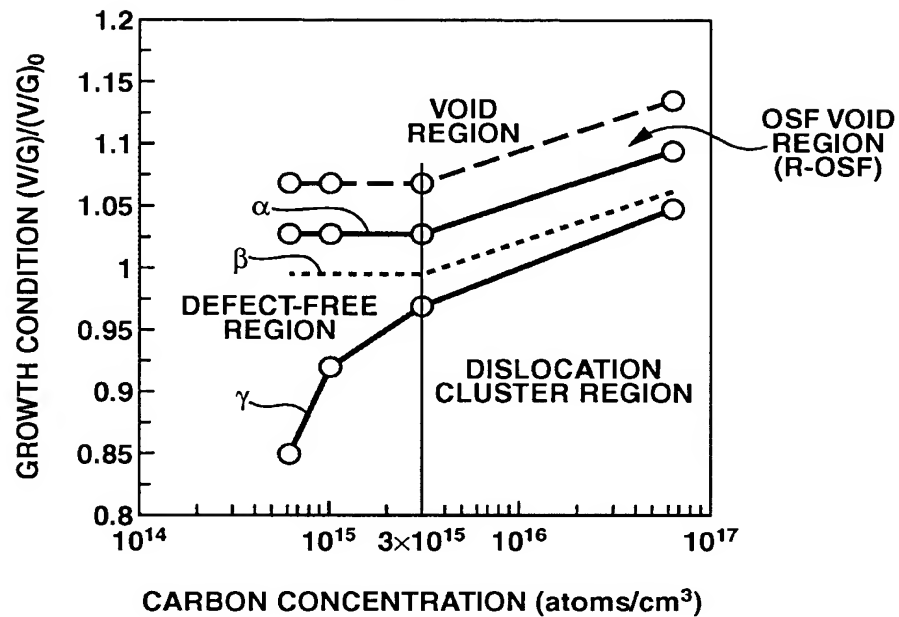


FIG.22

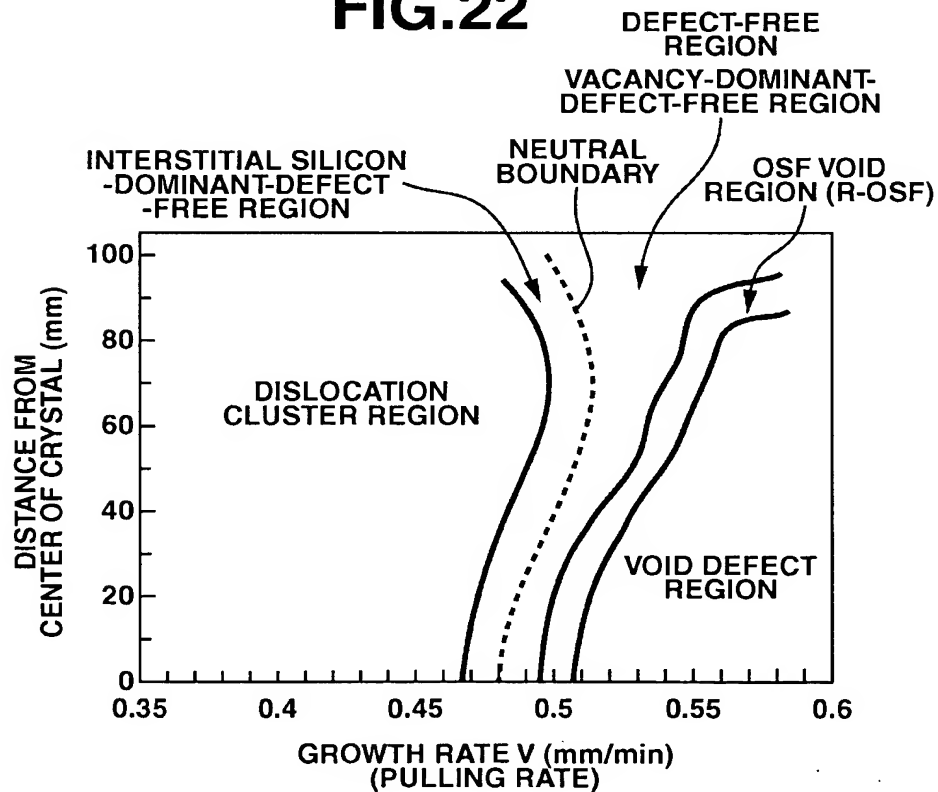
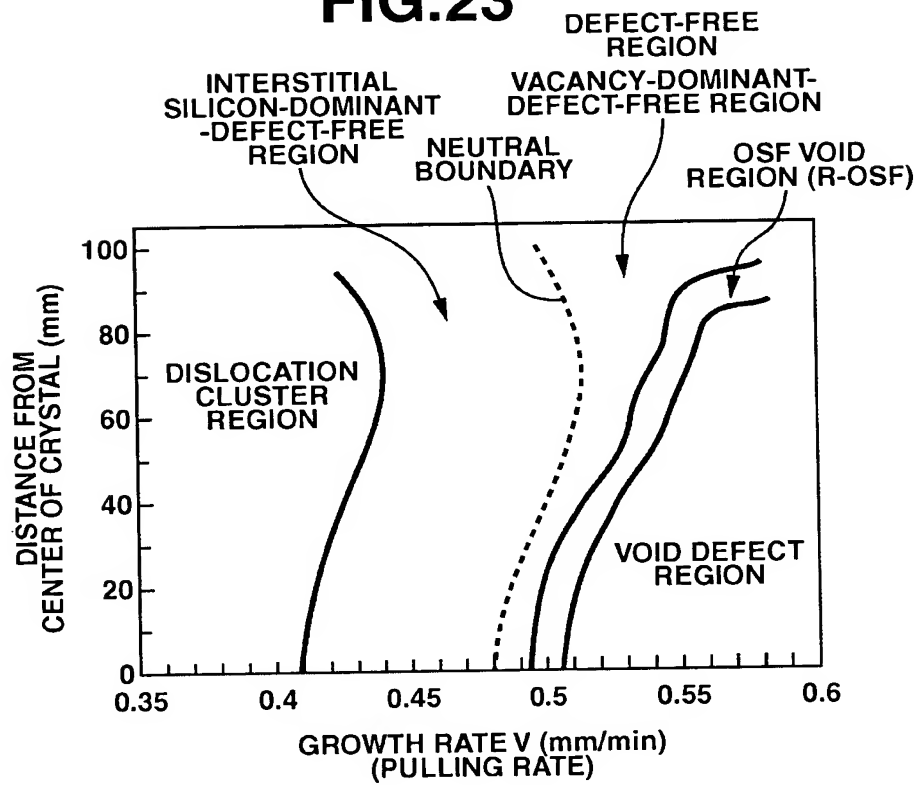


FIG.23**FIG.24**

RELATIONSHIP BETWEEN CARBON CONCENTRATION AND $(V/G)/(V/G)_0$ AT THE BOUNDARY AT WHICH THE DEFECT TYPE CHANGES

CARBON CONCENTRATION (atoms/cm ³)	OSF BOUNDARY α (LOW V SIDE)	NEUTRAL POSITION β	DISLOCATION CLUSTER GENERATION BOUNDARY γ
6×10^{14}	1.03	1.00	0.85
1×10^{15}	1.03	1.00	0.92
3×10^{15}	1.03	1.00	0.97
6×10^{16}	1.095	1.07	1.05

FIG.25

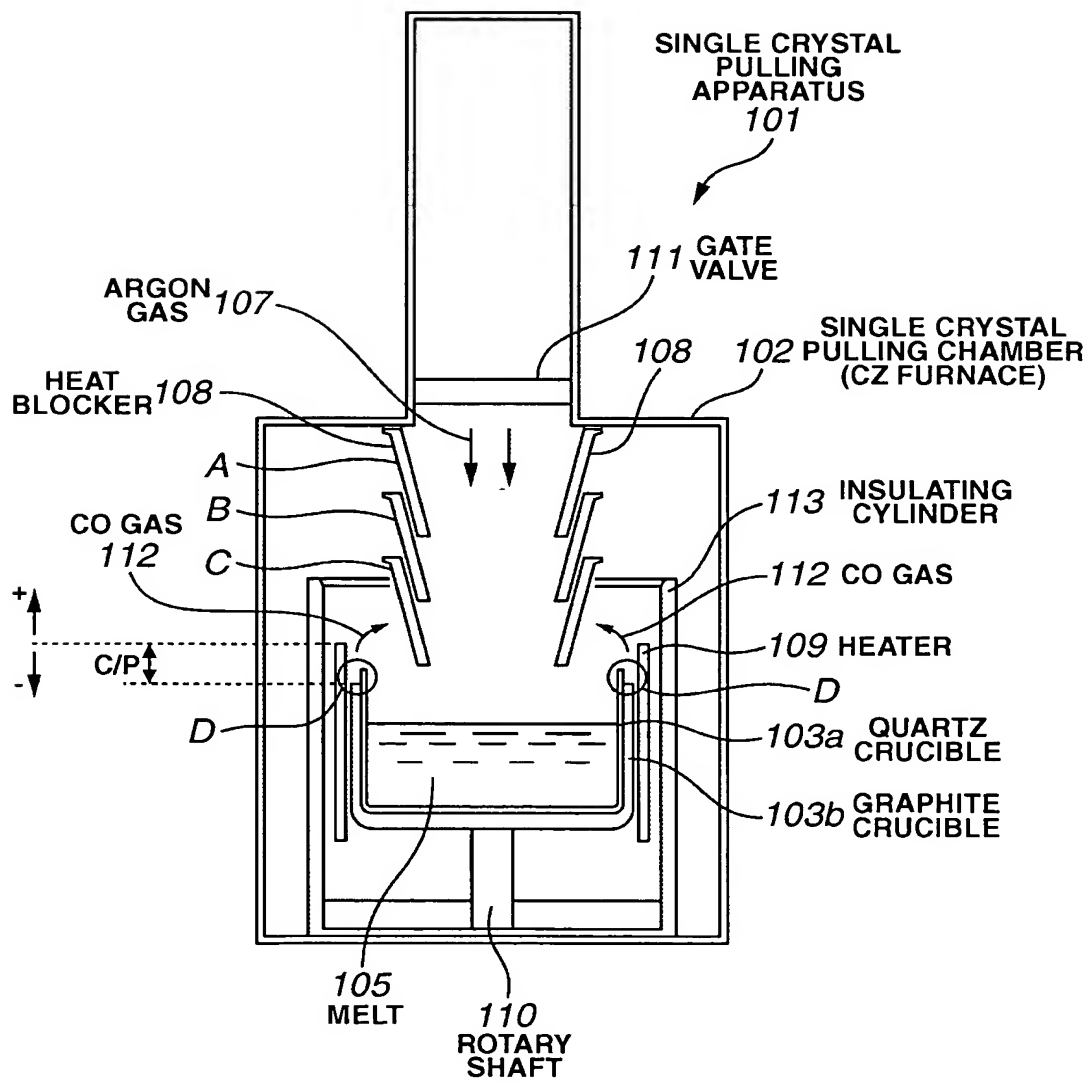


FIG.26

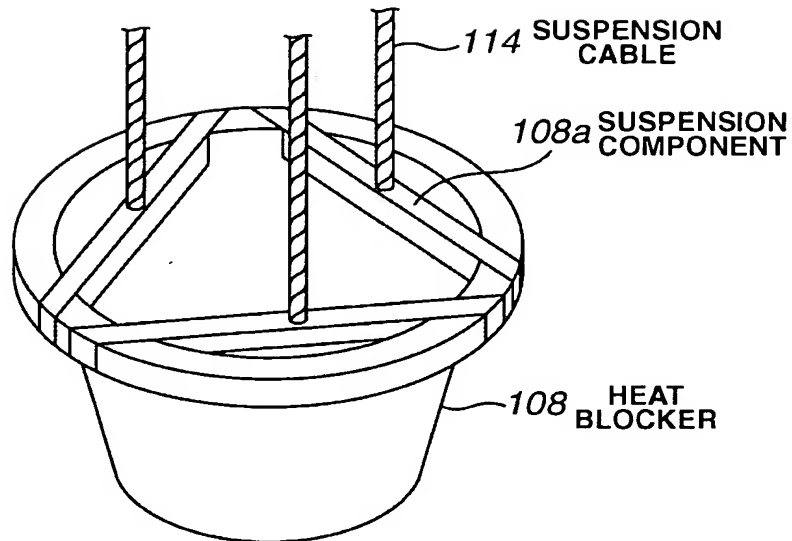


FIG.27

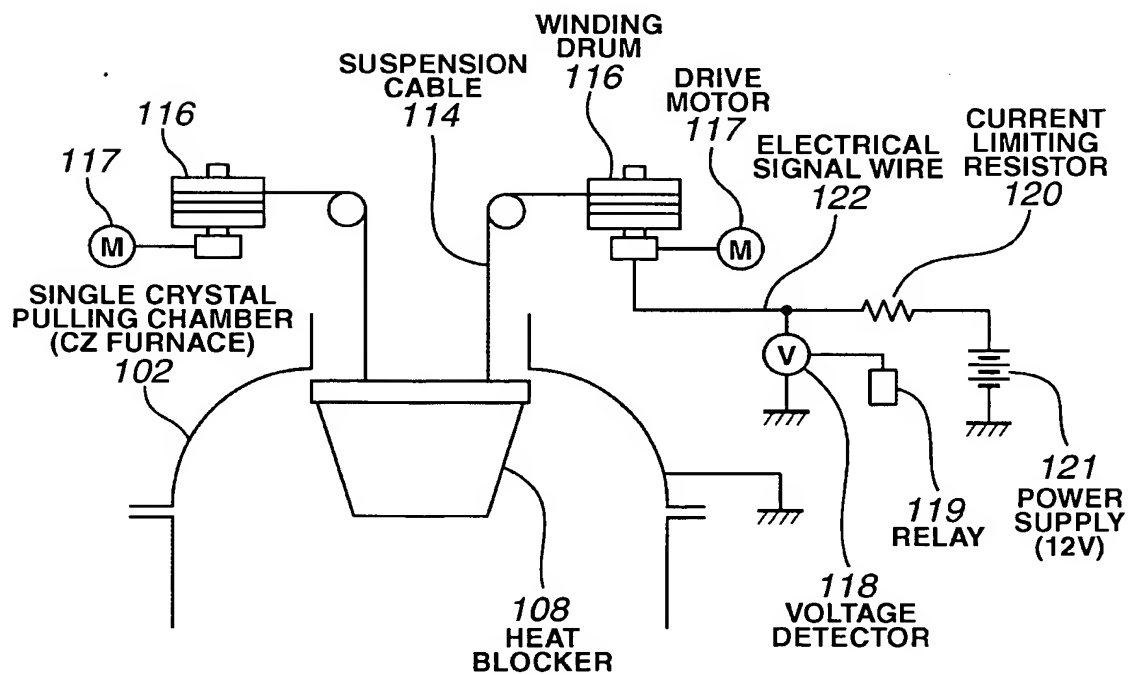
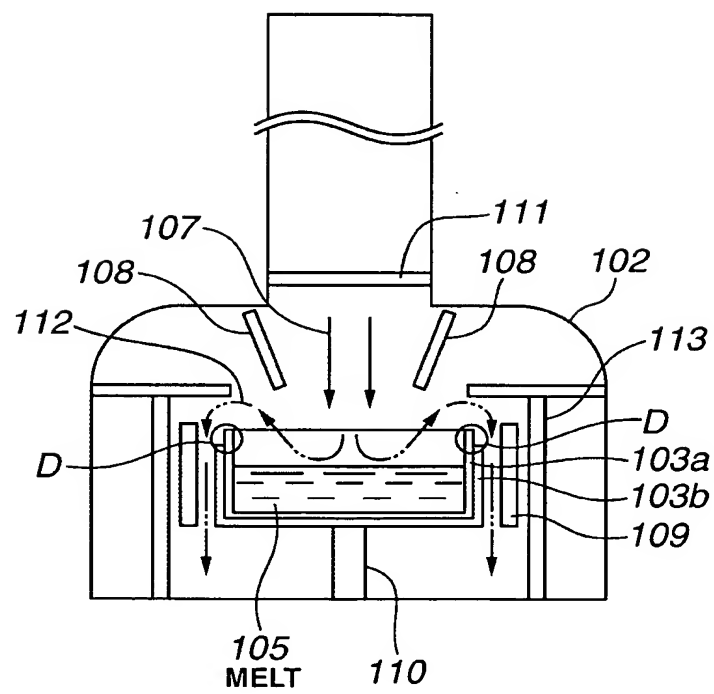


FIG.28



PRIOR ART **FIG.29**

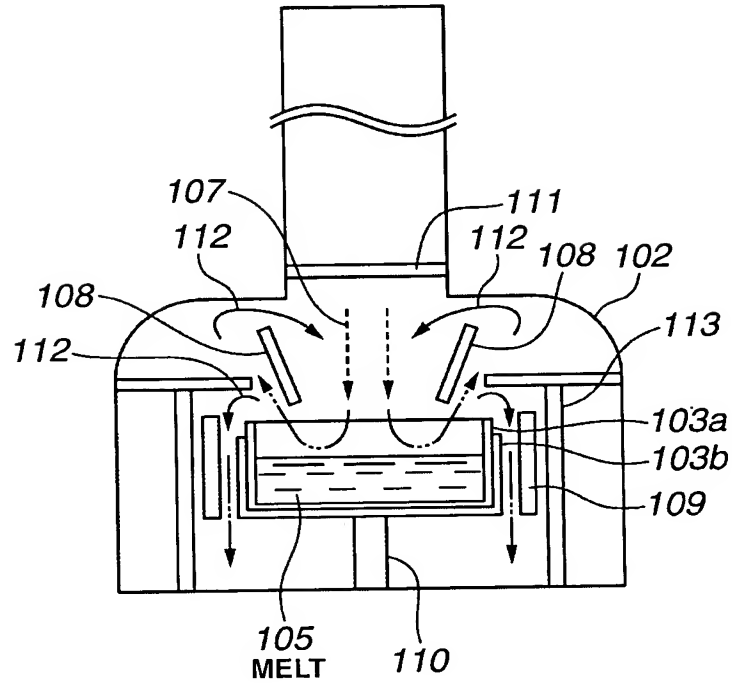


FIG.30

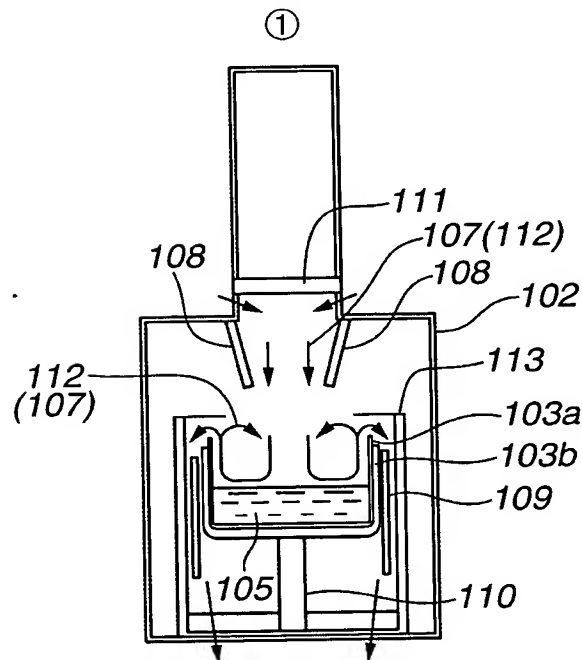


FIG.31

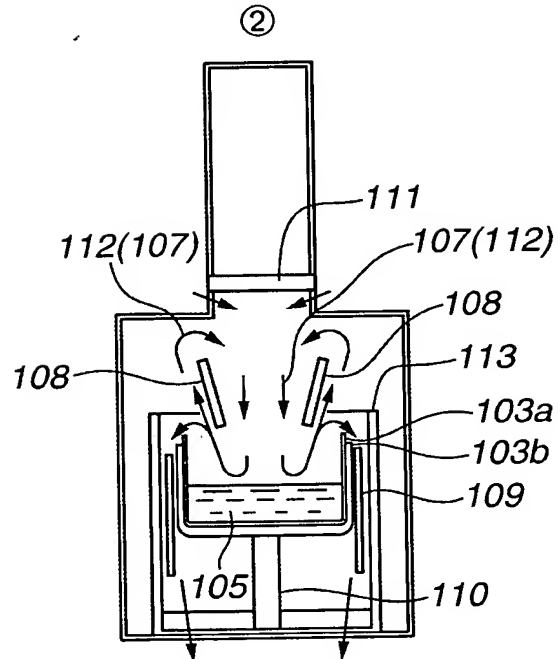


FIG.32

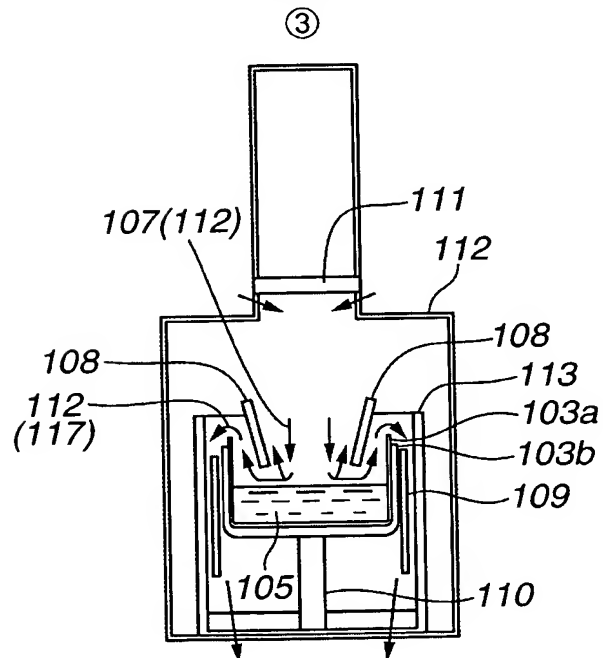


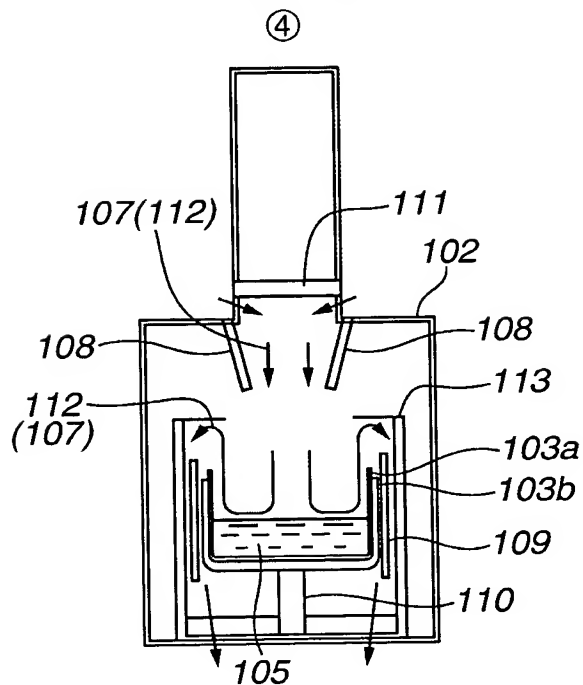
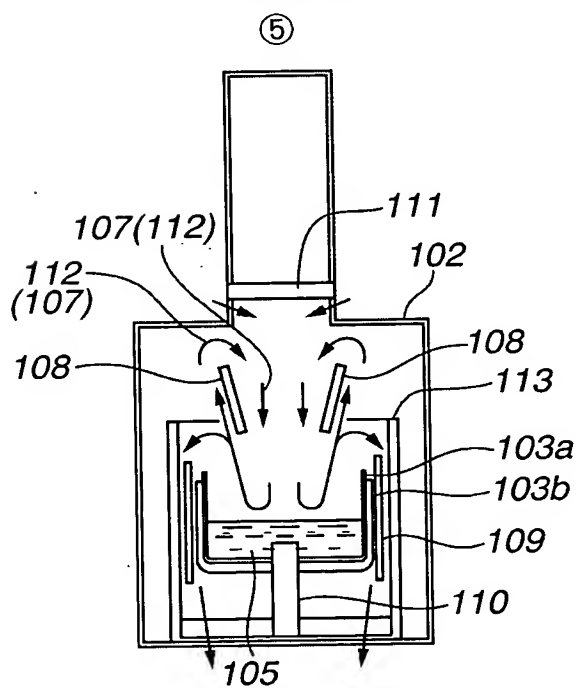
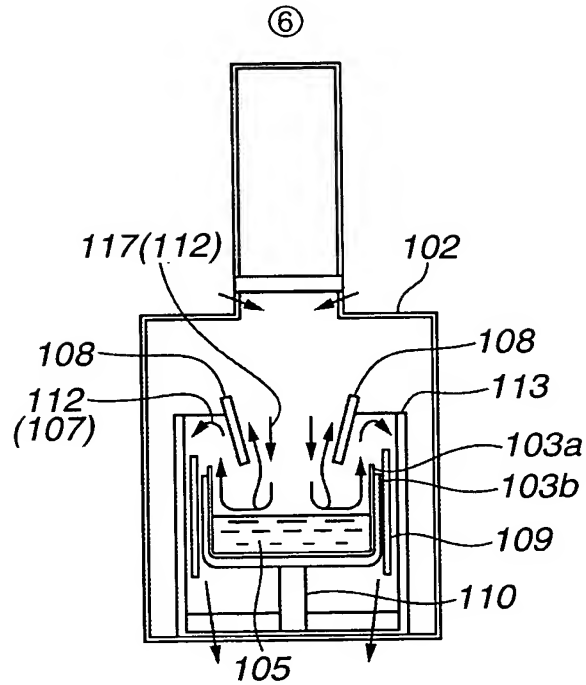
FIG.33**FIG.34**

FIG.35**FIG.36**

LEVEL	HEAT BLOCKER POSITION	CRUCIBLE POSITION C/P	CARBON CONCENTRATION RANKING (FROM LOWEST)
①	A	23	(2)
②	B	23	(6)
③	C	23	(4)
④	A	-100	(1)
⑤	B	-100	(5)
⑥	C	-100	(3)

FIG.37CARBON CONCENTRATION (E17 atoms/cm³)

CRUCIBLE POSITION C/P (mm)	GAS FLOW (L/min)	
	80	120
30	0.08~0.09	0.08~0.09
-70		